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Research Article

Prevalence of Types of Corneal Astigmatism before Cataract Surgery

AMIN NAJAFI[1], HABIB OJAGHI[1*], TELMA ZAHIRIAN MOGHADAM[2], AFSHAN SHARGHI[3]
[1] Department of Surgery, School of Medicine and Allied Medical Sciences Imam Reza Hospital, Ardabil University of Medical Sciences, Ardabil, Iran
[2] Social Determinants of Health Research Center, Ardabil University of Medical Sciences, Ardabil, Iran.
[3] School of Medicine and Allied Medical Sciences, Ardabil University of Medical Sciences, Ardabil, Iran.
*Corresponding author
Email ID: habibojaghi@yahoo.com
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ABSTRACT

PURPOSE: The current study was performed to analyze the prevalence and presentation patterns of corneal astigmatism types in cataract surgery candidates.

METHODS: Preoperative corneal astigmatism were prospectively measured with Autokeratometer in 780 patients (1018 eyes) during the year (2018) in cataract surgery (phacoemulsification) candidates. Descriptive and analytical statistics of astigmatism severity and keratometric data were performed based on age and sex.

RESULTS: A total of 1018 eyes of 780 patients were included in the present study, of which 445 (57.1%) were female and 335 (42.9%) were male. Of the 1018 evaluated eyes, 590 (58%) were female and 428 (42%) were male. The mean age of the patients was determined as 65.88 ± 11.43 years. The mean flat and steep-axis keratometric values were recorded as 44.75 ± 1.86 D and 43.82 ± 1.69 D, respectively. Women showed significantly steeper corneas. Based on LOCS III system, the types of cataracts were as follows: Posterior subcapsular 37.4%, nuclear 28%, cortical 1%, and mixed 33.6%. Types of astigmatism were as follows: 34.7% with-the-rule (WTR), 29.3% against-the-rule (ATR), 35.3% oblique and 0.7% had no astigmatism. A significant relationship of the type of astigmatism with gender and age group was observed (P <0.001), where the prevalence of WTR and ATR were found to be higher among women and men, respectively. The prevalence of WTR was higher among lower age groups, while the prevalence of ATR was found to be higher among older age groups. Furthermore, 70.8% of the eyes revealed astigmatism of at least 0.5 diopters, followed by astigmatism of at least 1 diopter (33.6%), astigmatism of at least 1.5 diopters (16.2%0, and astigmatism of at least 2 diopters (9.2%).

CONCLUSIONS: The Findings showed a significant prevalence of astigmatism greater than one diopters in these patients. The results of the study could provide valuable data for cataract surgeons and IOL manufacturers regarding the prevalence and type of corneal stigmatism.

Keywords: Cataract surgery, corneal astigmatism, keratometry, WTR, ATR, Oblique.

INTRODUCTION

Cataract surgery is one of the most common surgeries in ophthalmology (1, 2) and that astigmatic correction during cataract surgery has recently been shown to important maximizing of visual acuity after cataract surgery (3, 4). The incision causes changes in the corneal curvature, which more precise and finer technique of operation will lead to fewer changes (5, 6). Astigmatism is considered as a type of refractive error in which the eye produces an image with multiple focal points on the retina and is divided into three types of with-the-rule (WTR), against-the-rule (ATR), and oblique astigmatism (7, 8). Astigmatism should be managed at the time of surgery to obtain the best results from surgery. Astigmatism can be correct by a variety of surgical techniques. Postoperative outcomes are associated with many variables including age, optical zone size, number of incisions made, depth and length of incision (7, 8). Due to advances in biometric devices and intraocular lens power (IOL) calculation, modern cataract surgeries are capable of providing refractive correction, with 0.5 diopters of the target spherical correction (2). Therefore, both spherical and corneal astigmatism errors should be considered and managed at the time of cataract surgery to obtain the best refractive results after surgery in cataract patients with corneal astigmatism (2, 9, 10).

The prevalence of different amounts of corneal astigmatism in surgical candidates has not been fully evaluated. Analysis of this can provide valuable information for cataract surgeons and IOL manufacturers. The important issue is to

select the parameters to optimize the production process, storage and clinical application when designing a toric IOL. There are currently few reports of systematic data on the prevalence of corneal astigmatism in large populations that can be used for large-scale production planning (9). Since corneal astigmatism can have different values in different populations, in this study we investigated the types of corneal astigmatism in patients undergoing cataract surgery in Noor Surgery Center, Ardabil, Iran.

MATERIALS AND METHODS

This descriptive-analytical study was performed on 780 patients (1018 eyes) who were candidates for consecutive cataract surgery at Noor Ophthalmology Clinic in Ardabil in 2018. Exclusion criteria included patients under 18 years of age, previous corneal surgery, previous eye trauma, irregular corneal astigmatism, and a history of inflammatory eye disease. Preoperative keratometric measurements were performed using a Canon RK-F2 Full Auto Ref-Keratometer (TOKYO, JAPAN). Patient information was then recorded in the checklist. SPSS software version 25 was used for data analysis.

Since all variables including severity of astigmatism, age, keratometric parameters (K1, K2, and mean K) had abnormal distributions, Correlation between parameters was analyzed using Spearman-U-Mann-Whitney and Kruskal-Wallis tests. Chi-square and Fisher exact tests were also used to compare the two class parameters. Significance level was considered less than 0.05.

RESULTS

In this study a total of 1018 eyes of 780 patients were studied, of which 445 (57.1%) were female and 335 (42.9%) were male. Of the 1018 evaluated eyes, 590 (58%) were female and 428 (42%) were male. Mean age of patients was determined 65.88 ± 11.43 years and mean age of female and male patients was recorded as 65.05 ± 10.93 years and 66.98±11.99%, respectively. The highest age group in this study was 61-70 years old (33%) followed by 71-80 years old (28.1%), (Figure 1).

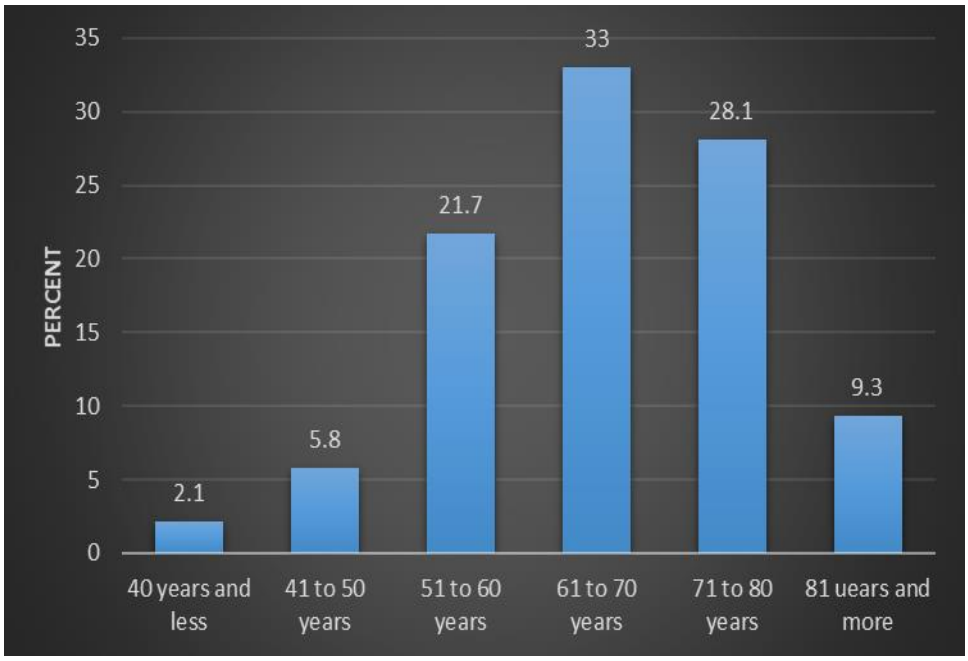

Fig.1: Frequency distribution of eyes examined by different age groups

Table 1 shows the severity and mean of astigmatism in the studied subjects, which the lowest and highest prevalence of astigmatism were reported to belong to ATR astigmatism (29.3%) and oblique astigmatism (35.3%), respectively.

In the current study, 0.7% of eyes do not appear to have astigmatism, and have spherical cornea. (Figure 2). Frequency distribution of types of astigmatism was significantly different between males and females (P <0.001). So that most women had astigmatism type of WTR and men had more ATR type. The proportion of oblique astigmatism in men and women is close to each other and the second most prevalent in each group.

Table 1: Mean and severity of astigmatism in the eyes examined by sex

Astigmatism type	Number	Mean	Standard Deviation	Middle	Female	Male	P-Value
WTR	353	1/07	1/09	0/75	234 (%39/9)	119 (%28/1)	P<0/001
ATR	298	0/97	0/83	0/75	130 (%22/1)	168 (%39/7)	
Oblique	359	0/78	0/92	0/5	223 (%38/0)	136 (%32/2)	
Sphere	8	–	–	–	–	–	
Total	1018	0/93	0/97	0/63	587	423	

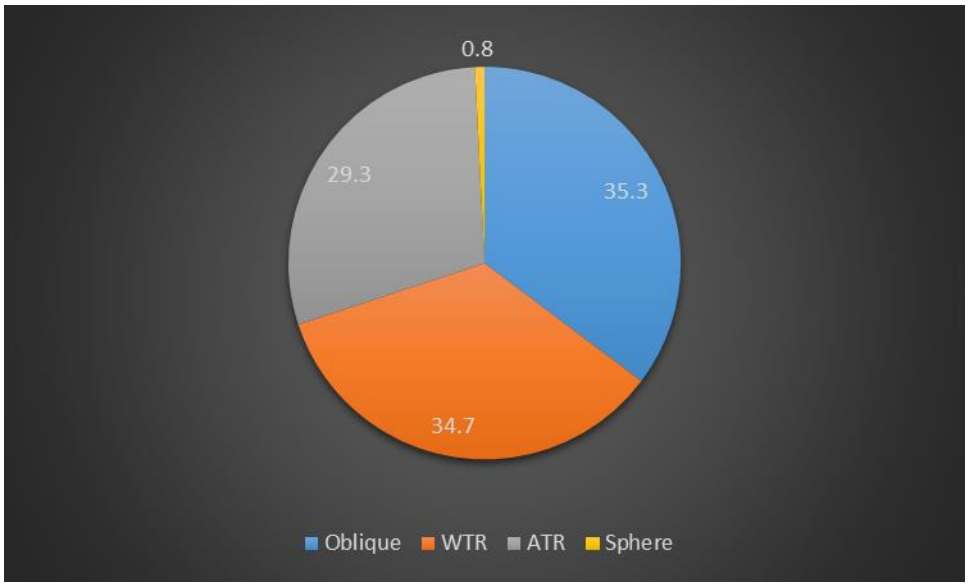

Fig.2: Frequency distribution of studied eyes in terms of type of astigmatism

Table 2 shows that the severity of astigmatism is not significantly different between both sexes (P = 0.141). Corneal keratometry in the flat (K1) and steep (K2) axes and mean keratometry were found to be significantly higher in females than males (P <0.001). Mean of steep meridian angle was not significantly different between both sexes (P = 0.138).

Table 2: Severity of astigmatism and keratometric findings in patients based on the sex

Characteristic		female	Male	P-Value
Severity of astigmatism		0/97±1/05	0/88±0/84	0/141
keratometry	K1	45/18±1/86	44/16±1/69	P<0/001
	K2	44/21±1/67	43/28±1/57	P<0/001
	Mean K	44/69±1/69	43/67±1/88	P<0/001
Steep meridian		93/79±48/16	98/49±57/43	0/138

Figure 3 shows the frequency distribution of the types of astigmatism in patients by age group, and the types of astigmatism showed a significant difference between the age groups (P <0.001) so that there was an age-related shift towards ATR astigmatism as age advances, where the highest severity of astigmatism was related to age ≤ 40 years.

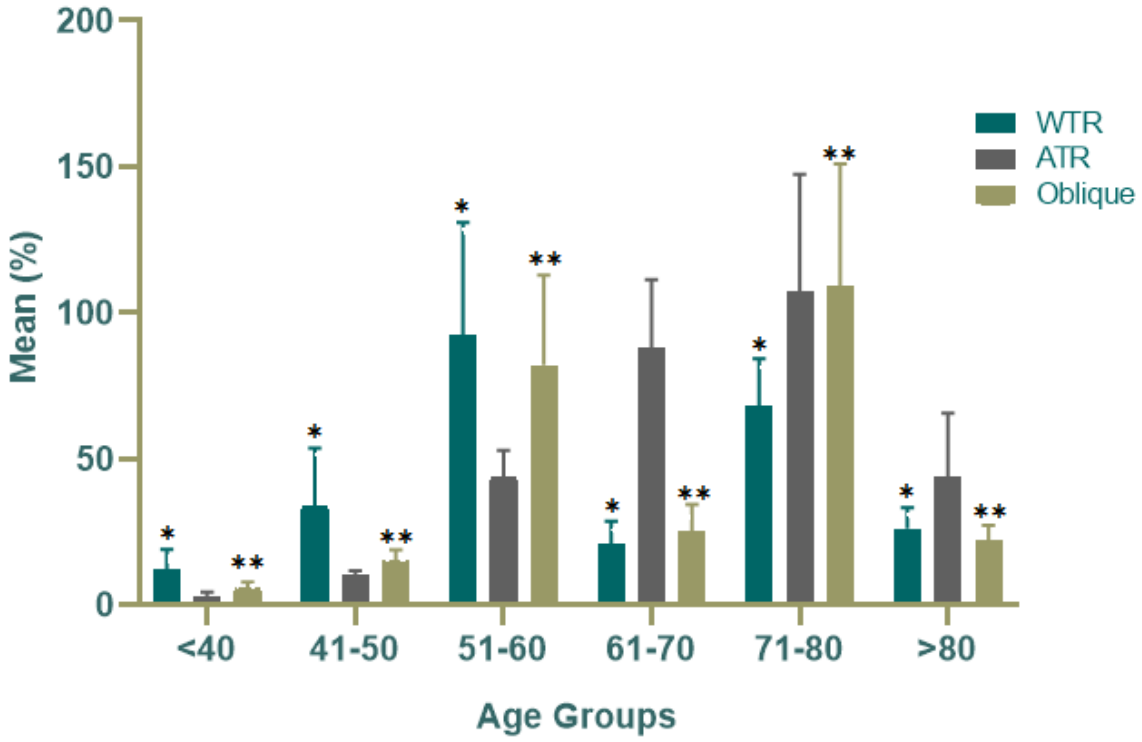

Figure 3: age group distribution of participants is shown in to three Astigmatism groups, where WTR=with-the-rule, ATR=against-the-rule and oblique. Based on the results, there were significant difference between age groups in term of Oblique and WTR (p<0.001), where *: Oblique is higher in 51 to 60 and 71 to 80 in compare with the other age groups significantly (p<0.001). In addition, **=WTR was higher in same groups in compare with other age groups significantly (p<0.001)

The mean keratometry values at the flat (K1) and steep (K2) axis, and mean keratometry (mean k) were significantly different between age groups, where most of the three belong to the age group of 61-70 years. Mean steep meridian angle was not significantly different between age groups (P = 0.371). Spearman correlation test did not reveal a significant relationship between age of patients and severity of astigmatism neither in all patients (r = -0.027 and P = 0.394) nor in patients with severity of astigmatism > 1 (r = +0.013 and P= 0.817 0).

Table 3: Severity of astigmatism and keratometric findings in patients based on the age groups.

age category	Number of eyes	The severity of astigmatism	Keratometry			Steep meridian
			K1	K2	Mean K	
Less than 40 years	21	1/28±1/13	43/48±2/64	42/19±1/92	42/83±2/24	104/05±37/77
50–41 years	59	1/24±0/94	44/61±1/86	43/37±1/64	43/99±1/69	98/97±36/81
60–51 years	221	0/84±0/83	44/63±1/60	43/78±1/50	44/21±1/49	100/86±46/18
70–61 years	336	0/91±1/10	44/99±1/99	44/08±1/77	44/54±1/80	96/08±50/70
80–71 years	286	0/83±0/84	44/63±1/75	43/79±1/66	44/14±2/09	91/15±57/70
More than 80 years	95	1/20±1/02	44/90±1/88	43/70±1/62	44/30±1/68	92/84±63/46
P-Value	-	<0/001	0/003	<0/001	0/001	0/371

DISCUSSION

Corneal astigmatism is an important factor that has a significant impact on postoperative visual acuity of the cataract surgery. In this study, 1018 eyes of 780 patients were studied, showing that a higher percentage of patients were female candidates for cataract surgery (female to male ratio: 1.3 fold). Similar findings have highlighted the higher prevalence of corneal astigmatism in female subjects scheduled for cataract surgery. The ratio of female to male was 1.2 times to 1.8 times (2, 11-17). However, an equal proportion of men and women have been reported as candidates for cataract surgery in some studies (18, 19). The mean age of our study population was 65.88 ± 11.43 years, which is comparable to the mean age of cataract surgery patients in more advanced countries, indicating that people in our area have the disease at an earlier age as the mean age was reported in the United Kingdom (78.84 ± 7.01 years) (11), Ireland (75.2 ± 10.57 years) (15), Argentina (71.9 ± 9.6 years) (12), Lithuania (71.68 ± 9.77 years) (13), and Portugal (69 ± 10 years) (14). All of which were found to be more than our study. But the mean age of these patients in Nepal and India was lower than in the present study (18-16). In this study, mean flat-axis keratometric value was found to be 43.82 ± 1.69 diopters, which is similar to that reported in a study in Tehran (43.7 ± 1.7 diopters) and India (43.87 ± 1.92 diopters), (2, 18); nevertheless, was higher than that reported in studies in Argentina (43 ± 1.5 diopters), Lithuania (43.53 ± 1.42 diopters), and Ireland (43.09 ±1.61 diopters), (12, 13, 15). The overall mean steep-axis keratometric value in the present study was 44.75±1.86 diopters, which is higher than that reported in studies in Argentina (44.1 ± 1.6 diopters), Lithuania (44.4±1.53 diopters), and Ireland (44.16 ± 1.62 diopters), (12, 13, 15); but it was lower than reported in a study in India (44.91 ±1.88 D) and Tehran (44.83 ± 1.79 D), (2, 18). Comparison of the flat and steep-axis keratometric values indicated that women had significantly steeper corners than men. Similar findings have been reported in various studies (2, 12-14, 18). Goto stated in his study that the differences in corneal curvature between men and women may be due to the influence of sex hormones (20).

There was a significant difference between different age groups in keratometry of the flat (K1) axis, steep-axis and mean. Generally, in various studies, flat and steep-axis keratometric values have shown an irregular pattern of age change. For example, in a study in India (18), flat and steep-axis keratometric value was significantly different between different age groups. In one study (2), there was a significant difference between the age groups in terms of flat and steep-axis keratometric values, both of which are consistent with the present study. But one study in Portugal by Ferreira et al. (14) reported no significant relationship of flat and steep-axis keratometric values with age, which is inconsistent with the present study.

Prevalence of types of WTR, ATR, and oblique astigmatism were similar among patients undergoing cataract surgery in the present study. WTR and oblique astigmatisms were in the first rank with frequencies of 35.3% and 34.7%, respectively, and ATR astigmatism showed a slightly lower frequency (29.3%). Unlike our study, ATR astigmatism has been reported to be the most common type of astigmatism reported with more difference than other types including England (42.5%) (11); Lithuania (56.9%) (13); Portugal (46.5%) (14); India (58%) (16) and Tehran (46.8%) (2). Chaudhary et al. in Nepal (17) and Ladeveze et al. in Argentina (12) also reported WTR with a prevalence of about 44%, which was found to be the most common type of astigmatism and was more prevalent than our study. Overall, the prevalence of WTR astigmatism has been reported in other studies between 26.9 and 44.4, which the results of our study were in the same range. The prevalence of ATR astigmatism has been reported between 39 and 58 in other studies, which were less prevalent in our study. The prevalence of oblique astigmatism was reported to be between 8 and 20.4%. The prevalence in our study was greater than this. The reason for the higher prevalence of ATR astigmatism in other studies than in our study may be due to the higher mean age of other studies, since ATR prevalence is generally more common in older age than other types of astigmatism. Another reason is related to the definition of the WTR and ATR angle range, so that in cases where the ±30 degrees of horizontal and vertical meridian range is defined for ATR and WTR, a high proportion of astigmatisms fall into the two ATR and WTR group relative to oblique astigmatism.

However, in cases where the ±20 degree (same as our study) or ± 22.5 degree (same as some of other studies) of horizontal and vertical meridian range for the ATR and WTR astigmatism is considered, more participants fall within the oblique astigmatism range. Table 4 summarizes the results of some studies in this area with the present study.

Table 4: Summary of studies

Parameter	Current study	Day	Ladeveze	Varoniukait	Ferreira	Curragh	Shori	Chaudhary	Prasher	Mohammadi	Gohari
Conurty/City	Ardabil	England	Argentina	Lithuania	Portuguese	Ireland	India	Nepal	India	Tehran	Yazd
Years	2019	2018	2018	2018	2017	2017	2017	2017	2016	2016	2016
Eye /patient	780 /1018	/110468 76910	/2136 1204	422 /502	/6506 6506	/2080 1788	/100 100	185 /225	2316 /2502	/2156 1317	/400 365
Female /male (%)	42.9 /57.1	40 /60	/58.4 41.6	35.5 /64.5	42.8 /57.2	41 /59	41 /59	38.7 /61.3	49.8 /50.2	46.2 /53.8	/49.9 50.1
Age (years) Mean ± SD	65/88±11/4	78/84±7/01	71/9±9/6	71/68±9/77	69±10	75/2±10/57	58/4±10	64/45±12/89	59/54±10/96	64/9±11/48	69/5
corneal astigmatism (Mean ± SD)	0/93±0/97	1/06±0/81	1/0±0/7	0/8±0/75	1/08±0/84	1/09±0/83	–	0/84±0/80	1/04±1/04	1/12±1/10	–
Keratometry) D ( ) Flat (K1) Steep (K2	 43/82±1/69 44/75±1/86	 – –	 43±1/5 44/1±1/6	 43/5±1/4 44/4±1/5	 – –	 43/09±1/61 44/16±1/62	 – –	 – –	 43/9±1/9 44/9±1/9	 43/7±1/7 44/83±1/79	 – –
corneal astigmatism (%) 0/5 ≤*diopter* 1 ≤*diopter* 1/5 ≤*diopter* 2 ≤*diopter*	 70/8 33/6 16/2 9/2	 78 42 21 11	 – 39 19 –	 51/6 23/3 10/6 7/4	 – 43/5 – –	 75 41/3 22/1 11/6	 – – – –	 – – 18 –	 – 38/17 – 9/55	 76/7 48/2 26/2 14/9	 – 43/2 22/2 9/3
astigmatism types (%) WTR ATR oblique	 34/7 29/3 35/3	 30/1 42/5 17	 44 39 17	 26/9 56/9 16/2	 33/1 46/5 20/4	 – – –	 34 58 8	 44/4 40/4 12/9	 28/3 51/9 19/8	 36/9 46/8 16/2	 – – –

The present study showed that there was a significant difference in the prevalence of different types of astigmatism between the sexes. That was similar to a study in Argentina (12).

The findings showed that there was a statistically significant relationship between the type of astigmatism and age groups so that WTR astigmatism was found to be the most prevalent type of astigmatism in the lower age groups while ATR astigmatism was more prevalent in the older age groups. In addition, in our study, a shift toward ATR astigmatism was observed with increasing age, indicating that ATR astigmatism was the lowest in the age group of ≤ 40 years old (14.3%). This type of astigmatism gradually increased with each decade of life, reaching its maximum value (48.9%) in the age group of 80 years and over.

The findings are consistent with the results of other studies (2, 11-13, 17, 18). These observations highlight the overcorrection in the ATR astigmatism and the undercorrection in WTR astigmatism in the older population (13). Increased prevalence of ATR with age may be due to sclerosis, fibrosis, decreased lens clarity in phakic individuals (2), or changes in corneal curvature due to decreased eyelid tension, which typically occurs with aging (21). The findings of our study showed that the majority of cataract surgery candidates (70.8%) had the least clinically significant astigmatism (0.5 to less than one diopter); in addition, more severe also included a significant proportion of our patients, with 33.6% of our patients showed at least 1 diopter astigmatism, followed by 1.5 (16.2%), and 2 diopters (9.2%). Other similar studies conducted on cataract surgery candidates show, the prevalence of higher degrees of astigmatism was greater than our patients, which the prevalence of 0.5, 1, 1,5, and 2 diopters was reported in the eyes of candidates for cataract surgery in a study in the United Kingdom (78%, 42%, 21%, and 11%, respectively) (11), Ireland (75%, 41.3%, 22.2% and 11.6%) (15), Tehran (76.7%, 48.2%, 26.2%, and 14.9%) (2). Furthermore, the prevalence of at least 1 diopter astigmatism was reported in a study in Argentina (39%), (12), Portugal (43.5%) (14), and India (38.17%) (18), which is more than the findings of our study. Gohari et al. in Yazd (19) also reported that 43.2% of eyes undergoing cataract surgery had astigmatism greater than 1 diopter and 22.2% had astigmatism greater than 1.5, which was more than our findings. But the frequency of astigmatisms with at least 0.5, 1, 1.5, and 2 diopters has been reported in the eyes of the candidate for cataract surgery in a study in Lithuania (51.6%, 23%, 10.6%, and 7.4% respectively), which is lower than the present study.

In addition, a study in Nepal (17) showed that 18% of eyes undergoing cataract surgery had astigmatism greater than 1.5 diopters. In a study in Yazd (19), 9.3% of eyes revealed astigmatism greater than 2 diopters, and 9.55% of eyes had astigmatism > 2 diopters in a study in India (18), which are similar to our findings (Table 4).

Overall, in previous studies, the prevalence of astigmatisms greater than 0.5 diopters was reported between 51.6% and 78%, followed by > 1 diopters (23.3%-48.2%), > 1.5 diopters (26.2% - 10.6%), and > 2 diopters (between 7.4%-14.9%) which the frequency of astigmatism with different severities in our study was also within these ranges. Astigmatism of less than 1 diopters gives patients a relatively good visual acuity, and these patients do not request correction. In most cases, however, Astigmatic refractive errors between 1 and 2 diopters was capable of reducing visual acuity between 20/30 and 20/50 and likewise, astigmatisms between 2 and 3 diopters can decrease visual acuity between 20/70 and 20/100 (12, 22).

Thus, our findings suggest that at least one third of patients undergoing cataract surgery also need astigmatism correction, which can benefit from correction during cataract surgery to improve visual outcomes. In the present study, although the severity of astigmatism was higher in women than in men, there was no significant relationship between gender and severity of astigmatism. This finding is consistent with other studies (12, 13, 15, 18).

In the present study, there was a statistically significant difference in the severity of astigmatism between the different age groups, but no regularity was observed between the severity of astigmatism with increasing or decreasing age group so that the highest intensity of astigmatism was in the age group of 40 years and younger that increasing age would decrease to the fifth and sixth decades of life, then, there was an increase in the seventh, a decrease in the eighth, and again an increase in the ninth decade.

Overall, the findings of studies on the relationship between age and severity of astigmatism in patients undergoing cataract surgery appear to be contradictory, so that some of the studies were consistent with the present study as a study by Chaudhary et al (2017) in Nepal (17) showed a significant difference in the severity of astigmatism between different age groups, where, in accordance with our findings, no regular association was found between the severity of astigmatism and the increase or decrease in age.

As data presented in our study, Prasher et al. (2016) in India (18) observed a significant relationship between the severity of stigmatism and age, but this relationship showed a more regular association in their study so that the intensity of corneal stigmatism gradually increased with age after the fourth decade of life. In other studies, no association was found between the age of patients undergoing cataract surgery and the severity of astigmatism (12, 13, 15, 19).

The high sample size that strengthens the results of the study and makes it possible to generalize the results is one of the most important strengths of the current study. The lack of some effective underlying variables such as location, daily exposure to the sun, as well as patients' occupation as a known factor in previous studies are the major limitations of this study that should be considered in future studies.

CONCLUSION

The results of this study showed that there is a significant incidence of astigmatism greater than 1 diopter preoperatively in these patients. The results of the study can provide valuable information for cataract surgeons and IOL manufacturers regarding the prevalence and type of corneal stigmatism. These findings highlight need to take measures for managing concomitant correction of astigmatism during cataract surgery and to further improve the visual outcomes in these patients.

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